Technetium

Symbol:	**Tc**
Atomic Number: *(protons in nucleus)*	**43**
Atomic Weight: *(not naturally occurring)*	**-**

What Is It? Technetium is a silvery gray metal that looks like platinum and tarnishes slowly in moist air. Essentially all the technetium on earth has been created by human activities involving fissionable materials. Taking its name from the Greek work *technetos* meaning artificial, it was first produced in 1937 by bombarding molybdenum with deuterons (a form of hydrogen with a neutron in the nucleus) in a cyclotron.

There are no stable, i.e., nonradioactive, isotopes of technetium. (Isotopes are different forms of an element that have the same number of protons in the nucleus but a different number of neutrons.) Of the ten major radioactive isotopes, only three – technetium-97, technetium-98 and technetium-99 – have half-lives sufficiently long to warrant concern over time. The half-lives of the other isotopes are less than 90 days. Only one of the three long-lived isotopes, technetium-99, is produced in sufficient quantities to be of concern at Department of Energy (DOE) environmental management sites such as Hanford. This fission product decays by emitting a beta particle to produce the stable isotope ruthenium-99. The very long half-life (and thus low specific activity) of technetium-99 limits its radioactive hazards.

Technetium-98 also decays by emitting a beta particle while technetium-97 decays by electron capture. These two radionuclides have very long half-lives (in excess of a million years). An additional radionuclide, technetium-99m (the "m" means metastable), is used in medical diagnostic procedures. This isotope has a half-life of about six hours and is a decay product of molybdenum-99, a radionuclide with a half-life of 66 hours that also decays by emitting a beta particle.

Radioactive Properties of Key Technetium Isotopes

Isotope	**Half-Life** *(yr)*	**Specific Activity** *(Ci/g)*	**Decay Mode**	**Radiation Energy** *(MeV)*		
				Alpha *(α)*	**Beta** *(β)*	**Gamma** *(γ)*
Tc-97	2.6 million	0.0014	EC	-	0.0056	0.011
Tc-98	4.2 million	0.00088	β	-	0.16	1.4
Tc-99	210,000	0.017	β	-	0.10	-

EC = electron capture, Ci = curie, g = gram, and MeV = million electron volts; a dash means the entry is not applicable. (See the companion fact sheet on Radioactive Properties, Internal Distribution, and Risk Coefficients for an explanation of terms and interpretation of radiation energies.) Values are given to two significant figures.

Where Does It Come From? Technetium is produced as a result of nuclear transformations, typically in a nuclear reactor. When an atom of a fissile nuclide such as uranium-235 fissions, it generally splits asymmetrically into two large fragments – fission products with mass numbers in the range of about 90 and 140 – and two or three neutrons. (The mass number is the sum of the number of protons and neutrons in the nucleus of the atom.) Technetium-99 and molybdenum-99 are two such fission products, with a relatively high yield of about 6%. That is, about six atoms of each isotope are produced per 100 fissions. Technetium-99m is a short-lived decay product of molybdenum-99. (An extremely small amount of technetium was created naturally in sustained underground nuclear reactions estimated to have occurred about 1.9 billion years ago in Gabon, Africa. This phenomenon occurred because much higher concentrations of uranium-235 were present at that time; the current uranium-235 concentration, about 0.72%, will not sustain such natural reactions.) Technetium-99 is a key radionuclide in spent nuclear fuel, high-level radioactive wastes resulting from processing spent fuel, and radioactive wastes associated with operating nuclear reactors and fuel reprocessing plants.

How Is It Used? Technetium is a very good corrosion inhibitor for steel, and protection can be achieved by adding only very small amounts during production. However, this use is limited by the radioactive nature of technetium. Technetium-99m is commonly used in nuclear medicine as a radioactive tracer. In this application, the radionuclide is chemically attached to a drug chosen for its tendency to collect in specific organs of the body, and the solution is then injected into the patient. After a short time (its half-life is only 6 hours), an image is collected with a radiosensitive detector for analysis. This technique is very useful in identifying cancer metastases in locations distant from primary tumors.

What's in the Environment? Technetium is not a naturally occurring element. Technetium-99 is present in soil due to fallout from past atmospheric nuclear weapons tests. Estimated concentrations in surface soil are very low, on the order of 0.0001 picocuries per gram (pCi/g), due to its low specific activity. Technetium-99 is very mobile in the environment, especially under aerobic conditions (i.e., where oxygen is present). From the surface it can move rapidly downward with percolating water because most technetium compounds do not bind well to soil particles. The concentration associated with sandy soil particles is estimated at 0.1 of that in interstitial water (in the pore spaces between the soil particles), although technetium binds more tightly to clay soils (with concentration ratios 10 times higher). For this reason, technetium-99 has been found in groundwater at several DOE sites. The highest concentrations of technetium-99 at Hanford are in areas that contain waste from processing irradiated fuel, such as in the tanks in the central portion of the site and to a lesser degree in the liquid disposal areas along the Columbia River. At Hanford, no significant concentration gradients have been observed or are predicted for the Columbia River; that is, technetium levels at and downstream of the site are similar to those upstream.

What Happens to It in the Body? Technetium pertechnetate (TcO_4) is readily taken up from the intestines and lungs following ingestion or inhalation, with about 50 to 80% of the amount ingested being transferred to the bloodstream. After reaching the blood, about 4% of the technetium pertechnetate deposits in the thyroid where it is retained with a biological half-life of 0.5 days; the other two organs to which this isotope preferentially distributes are the stomach wall (10%) and liver (3%). The rest of what enters the blood is uniformly distributed throughout all other organs and tissues with a short residence time. Of the amount that reaches body tissues, half is excreted in urine and half is excreted in feces. For the technetium that is distributed to organs other than the thyroid, about 75% leaves the body with a biological half-life of 1.6 days, 20% clears with a half-life of 3.7 days, and 5% clears with a half-life of 22 days. (This information is per simplified models that do not reflect intermediate redistribution.)

What Are the Primary Health Effects? Technetium-99 is a health hazard only if it is taken into the body. It does not pose an external hazard because it decays by emitting a relatively low-energy beta particle with no gamma radiation. The main concern is cancer induction from the beta particles associated with its radioactive decay. Technetium can concentrate in several organs depending on its chemical form, so there is no primary organ of concern. This is one reason why the short-lived isotope technetium-99m has such wide usage in nuclear medicine as a diagnostic tool. The low energy of the beta particle, the lack of significant gamma or X-rays, and the rapid excretion of technetium-99 from the body limit the potential for health effects.

What Is the Risk? Lifetime cancer mortality risk coefficients have been calculated for nearly all radionuclides, including technetium *(see box at right).* While the coefficients for ingestion are somewhat lower than for inhalation, ingestion is generally the most common means of entry into the body. Similar to other radionuclides, the risk coefficients for tap water are about 70% of those for dietary ingestion.

Radiological Risk Coefficients

This table provides selected risk coefficients for inhalation and ingestion. Recommended default absorption types were used for inhalation, and dietary values were used for ingestion. Risks are for lifetime cancer mortality per unit intake (pCi), averaged over all ages and both genders (10^{-12} is a trillionth). Other values, including for morbidity, are also available.

Isotope	Lifetime Cancer Mortality Risk	
	Inhalation *(pCi^{-1})*	**Ingestion** *(pCi^{-1})*
Technetium-97	7.6×10^{-13}	2.3×10^{-13}
Technetium-98	2.6×10^{-11}	6.0×10^{-12}
Technetium-99	1.3×10^{-11}	2.3×10^{-12}

For more information, see the companion fact sheet on Radioactive Properties, Internal Distribution, and Risk Coefficients and the accompanying Table 1.